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CONCEPTS FOR MARINE SURVIVAL CAPSULE

Prepared for
THE TRANSPORTATION DEVELOPMENT CENTRE

by
Bert van Leeuwen Industrial Design Ltd

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CONCEPTS FOR MARINE SURVIVAL CAPSULE

by

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17. Abstract

This report describes a feasibility study conducted from October 1982 to April 1983 concerning improvements, conceptual designs, and proposed design specifications for marine survival capsules. The report provides typical environmental conditions that marine survival equipment in the north Atlantic must withstand. It defines the various parameters associated with the design of marine survival equipment, and provides various design options for such equipment. Each design option is further analysed as for its relative economic worth as well as its relative functional worth The report concludes with a list of recommendations for the design of marine life-saving systems.

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17. Résume

Ce rapport traite d'une étude de faisabilité menée entre octobre 1982 et avril 1983 concernant des engins de sauvetage en mer, notamment divers concepts, perfectionnements et projets de spécifications. Il décrit les conditions atmosphériques et les états de mer typiques que ces engins devront affronter dans l'Atlantique nord. Il définit les paramètres se rapportant à la conception des engins de sauvetage en mer et dégage les diverses options qui peuvent se présenter, chacune de ces options étant ensuite étudiée du point de vue technico-économique. Enfin, il fait des recommendations concernant la conception de systèmes intéressant le sauvetage en mer.

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"Love is conferring survival benefits to others"

(Ashley Montague)

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1. INTRODUCTION

The Think Tank on Marine Disasters [1] encouraged development of concepts, leading to design improvements in ocean survival equipment.

This report concerns the feasibility of improved survival capsules and compares existing and proposed novel designs, using techniques of value engineering. Its purpose is to improve the safety of marine navigation in Canada's coastal and arctic waters.

Every year about 103 persons die in marine accidents that occur within Canadian jurisdiction. If slips and falls from stationary vessels are discounted, the total is about 91. Seven fatalities are fire/explosion related. The rest, 84, are mainly caused by drowning or hypothermia. [2]

The technology being developed will allow us to cope with a sometimes extremely hostile environment and have spin-offs for manufacturers.

Because of the nature of the design process, the scope of this report seems weighted in favour of background information, at the expense of the specific objective of developing conceptual designs and specifications for three types of survival capsules. The advantage is obvious to other design professionals who peruse its contents.

In the course of this study it became apparent that essential design information was not available in the areas of inherent stability of passive capsules under emergency conditions, water impact of blunt bodies, drag coefficients of various shapes in rough water and storm conditions, to name a few. There are some references about the dynamic behaviour of traditional craft [33][35], an area neglected by most naval scientists. Hulls patterned after traditional lifeboats may be designed to be self-righting; it does not take many rolls to eliminate the survivors. [31]

The conceptual designs (Fig. 2, 3 and 4) are therefore tentative, pending further work on inherent stability and model tests to verify the assumptions made. [69]

The report ends with a "first pass" analysis of a number of design options and compares them with the parameters and the estimated cost. It seems to indicate that a float-off superstructure or a detachable wheelhouse/command capsule may eliminate lifeboats as the most economical and functional design solution.

It is hoped that this study will assist in developing strategies for improved ocean safety.

2. GENERAL

2.1 The Environment

The decision as to which environment should form the basis for design activities has important consequences. Engineering is continually faced with "acceptable risk" decisions. The perception of risk changes with new data and understanding as well as cultural change.

Table 1 shows tentative environmental constraints for the North Atlantic:

Water Design Temperature	-2C to 23C (28F to 75F)
Air Design Temperature	-10C to 20C (14F to 68F)
Relative Humidity	50 to 100%
Wave Height	4 - 8 m (12'-25') normal
	25 m (80 ') maximum
Wave Period	6 - 10 secs normal
	22 secs maximum
Wind Velocity	51.4 m/sec (100 kt) maximum
Horizontal Acceleration (est.)	3.6 m/sec^2 (12 ft/sec^2) maximum
Vertical Acceleration	3 m/sec^2 (10 ft/sec^2) maximum
	10 m/sec^2 (32 ft/sec^2) (breaking wave)
High Point Velocity	6 m/sec (20 ft/sec) maximum

Note: 98.5 % of all waves will be less than 6.5 m (21 ft), which equals Sea State 6, steepness ratio 1/20, period 9 sec, velocity 15 m/sec (29 kt)

Supply Ship Dynamics:

	During rescue attempt		Worst Condition	
Component	Amplitude	Period	Amplitude	Period
Roll	$\pm 8^o$	15 sec	$\pm 30^o$	5 - 15 sec
Pitch	$\pm 2^o$	8 sec	$\pm 10^o$	5 - 15 sec
Heave	$\pm$ 3 m (10 ft)	9 sec	$\pm$ 12.5 m	
Sheer	$\pm$ 1.5 m (5 ft)	14 sec	no data	
Yaw	$\pm 1.5^o$	16 sec	no data	

Table 1 North Atlantic Conditions [3] [7] [8] [63]

2.2 Statistics

Rough seas occur about 5% of the time; storms often subside in 24 hours; 3 day survival should be aimed for. [1]

Abandonments: 21% in lifeboats; 24% in liferafts; 37% jump overboard. [15]

United Kingdom fishing vessel accident rate is 12 times industrial average; suggested cause is numbing cold. [16]

West Coast liferaft reliability is 90% [1] group J; 40% of those going to sea are MED (Marine Emergency Duties) trained.

In case of fire on board, firemen's injuries probably apply: 45% have heart attacks, probable cause: hyperthermia due to protective clothing and 13% suffer burns or smoke inhalation. (Source: CBC "Quirks & Quarks")

Vessel size over 10 000 T accounts for 1/3 of all fatalities, rest is spread evenly over the smaller size categories.[2]

3. EMERGENCY

3.1 Pre-Abandonment

Pre-Abandonment is the state of readiness before marine emergencies occur. The equipment should be ship-shape and the crew and passengers should know what to do. There is no substitute for competence when lives are at stake; the overwhelming conclusion of seminars on safety is the need for drills and training.[1]

Marine Emergency Duties (MED) Training should be mandatory for all who make a living on the water.[54] [55]

Despite the recommendations suggested worldwide, a large group of potential victims, such as passengers, will remain untrained and uninformed. There is a reluctance to use the available wall space for safety related information.

Ideally, abandonment need not occur in most disasters. Vessels can be designed to meet safe swampability requirements already common to pleasure craft or survival craft. Lifeboats and survival capsules ought to be able to prevent secondary abandonment until the moment of rescue.

3.2 Abandonment

3.2.1 Escape and Entry

Egress from wherever a person is located to a designated survival location constitutes abandonment. Passageways and signage designs should allow unimpeded traffic flow, even during power failure, list and slippery conditions. The problems are amplified on passenger ships and ferries, where crowds containing handicaps, including those of age, present the most difficult design problem.

Quick and dry access and entry of capsules is an essential design feature. Drilling platforms in deep water up to 200 or 300 m could incorporate a pressure-tight compartment with submersible lock-out, as suggested by Dr R L G Gilbert of the Bedford Institute. Crew could go to the compartment and wait to be rescued when the storm has abated, by standard submersibles, which at present are available and looking for something to do.

3.2.2 Launch

Accidental launch or "Man Overboard" is quite common. Jumping overboard by those not properly trained could be caused by a natural "flight reflex" or "escape reflex". If followed by sudden cold immersion, the "dive reflex" could cause drowning by inhaling water involuntarily.[45] p.9

Expert swimmers may be tempted to dive head first; clothing and some survival suits for accidental immersion in cold water may not be self-righting in that case and cause drowning.

Launching while underway (i.e.parent ship moving) has been the underlying concept of the conventional lifeboat, no doubt reinforced by the historic desire to reach safe shores in the absence of communication. [42]

Enclosed or covered lifeboats are a refinement of this concept. Some designs are now trending to oval and round capsules in plan form, with enough propulsion to avoid obstacles.

Inflatable liferafts and other passive, lightweight capsules depend on wind and water currents and manpower after launch. Their speed depends on wind drag vs shallowness of draft. Slide launch of passengers into inflatable collector platforms, with ready liferafts attached is being used on high-speed craft as well as large ferries. [18] p.111, [14] p.298, [36]

Concepts that have hardly been explored are: parachutes, parafoils, air-filled bags or balloons, drogue lines with cable-car capsules, submersibles, torpedo launch, ballistic launch, kite launch, lighter-than-air vehicle launch or combinations thereof and built-in submersible compartments.

Stern launch with water impact has been successfully tried in Norway with totally enclosed Harding lifeboats from 20 m heights. [38] [39]

Capsule models have been launched in wave tanks, allowing the crest of the passing wave to release the single fall line and carry the capsule along.

There is little information on water impact and deceleration of potentially interesting shapes for capsule designers. [20 to 28] [14] p.304

Technology transfer from automotive bumper and crash barrier designs will allow tolerable deceleration rates for humans.

Passive launch would allow the "abandon ship" command to be changed to: "man survival stations" while staying with the largest object afloat. In case of fires and explosions, one of these could become a survival command post and control nearby fires as well. If properly designed, a slide could allow gravity or power assisted launch from within. [52] p.237

3.2.3 Stand-off

Stand-off is the deliberate decision to stay near the disaster site in an alternate structure. This could be a semi-permanent attachment as has been proposed for oil rigs. Modern cargo transfer methods [3] could be used to connect a satellite attachment or a supply ship on standby duty and transfer people in lightweight freight modules.

Search and Rescue prefer survivors near the last known position, because a moving target may require extensive search patterns, delaying detection and recovery operations. Why the need for durable, 10 000 hour engines for lifeboats with only 1 to 10 hours of fuel when stand-off can be attained in 10 minutes ? This latter interval is a most critical period for passive capsules, requiring inherent stability before water ballast and surface stabilizers are deployed.

3.2.4 Propulsion

In self-propelled life-saving equipment, the cost of a complete installation of engine, fuel supply, drive and propeller system may run as high as 30% of the total cost of the capsule. Air driven motors have been used in prototypes, based on torpedo technology. High speed small diesel engines are rugged and reliable mass products, very light, guaranteed to start under the most adverse conditions and will last at least 100 hours under full throttle intermittent use.

Propellers or pumps could be driven via flexible shaft or hydraulic motor, allowing freedom in locating the engines.

Man-powered propulsion, other than oars, could be the reciprocating umbrella type as proposed by R B Fuller, the track-mounted paddle system or the skulling with twin flippers as proposed by the author. [41]

Wind-powered propulsion ranges from sails to kites, spinnakers and balloons as well as fixed protrusions on capsules. [40]

3.3 Survival

3.3.1 Buoyancy

Small pleasure craft often use foam for flotation and the regulations of the various authorities and voluntary manufacturer's design standards have contributed to the successful development of designs with benign swamping behaviour.

It is amazing that this proven technology has not been transferred to ocean going vessels, increasing ship survival rate. On most ships, the number of watertight compartments is too small for the size of the threat. Closed foam cells provide millions of watertight compartments. Monsanto has an instant foam, capable of deployment at depths of 5 m. Present use is limited to military inflatables and dinghies. It was developed to cope with bullet hole damage as well as to prevent paratrooper drowning. [50]

Flexible liferafts are equipped with multi-chamber inflatable rings and pockets, but an average of 7 chambers is not enough. Present technology is based on re-use, long life and annual mandatory testing with unacceptable failure rates.

Attempts at foam injection by some of the manufacturers showed their inability to completely fill the chambers with foam. Rigid foams hinder flexibility, which is one of the advantages of liferaft design.

The more clothes a person wears, the better he will float. [44] Survival/Immersion suits are boyant by themselves and some allow inflation through an attached mouthpiece.

J P Stevens & Co sold an expandable fabric based on Hansen's US Patent 3 607 591. The Ontario Research Foundation used pyrotechnics or fireworks in 1964 to initiate expanded fabric. [64]

The author's experiments with small balloons point at a possibility of arrays of small, light inflatables for upright flotation while providing some face protection with visibility. [34]

Ideally, most of the buoyancy should be provided near the "swampline". In steel hulls this could mean flooding the engine room while the main deck structure provides flotation during imminent capsizing.

3.3.2 Stability Research

Calm water static stability tests provide little information about dynamic behaviour of passive, shallow draft objects. [4]
Knowledge of small vessel dynamics in heavy seas and high winds may have been much more widespread among primitive mariners. [33] [35]
Naydler tested the "Puffin", a fiberglass transatlantic rowboat, after the loss of its crew. It concludes that keels may cause capsizing. [31]
The author sent a model of a Benjamin steel capsule to Dr Muggeridge of Memorial University, for testing under various drag and ballast conditions in a wave tank. [69]

Mr Chris Cooper, P.Eng., a DFO (Dept of Fisheries & Oceans) naval architect is identifying information gaps regarding dynamic stability He showed pictures of recent Japanese fishing boats with inflatable bags, externally mounted, to prevent capsizing.

Preliminary theoretical analysis of flat bottomed hemispheric shapes show the possibility of non-capsizing, depending on suitable weight/lift ratio.

3.3.3 Self-righting Concept

The difficulty with the self-righting concept is the capsizing implication, which is not going to be limited to a one-time event.

Most ships are stable under power and control. Their behaviour as a derelict, passive object is often not known and expected to be very frightening. The seamanship of the crew may show ability in deploying anchors and streaming warps in time, but often the longitudinal hull shape has already moved broadside. [31] [34]

Experiments have shown that smaller vessels with keels can capsize while drifting abeam down the slope of a wave. [31] The effect on the crew is worse than on the passengers in a rolling automobile. See also [7] pp 399,400

Shallow draft vessels, like dories and rafts seem to follow the ocean surface. [5] [33] [34] [35]

3.3.4 Inherent Stability

Non-self-righting designs are stable after capsizing, with trimarans showing the best upside down performance.[32] Nature inspires stability in jellyfish and nobody has yet reported capsized duckweed. Relatively fast surface skimming insects maintain dry bodies.

Flotation rings may work well [30] and streaming warps or drogues have been essential many times. [6] [16] p 45 [19]

Vertically stable cylindrical shapes have been used for wave research, with horizontal protrusions reducing heave. [29]

Ballasting traditionally provides inherent stability but integral ballasting of capsules reduces the payload of the main vessel. Liferafts use water ballast after launch with pouches, skirts (Avon) or large, valved waterbags (TUL-Givens Buoy).

Similar results are possible with rope suspended waterbags, ring nets, open cells like metallic foams, elastomeric sponges or extensions of mechanical features in rigid capsules.

Surface skimming devices need large area or perimeter stabilizers and the effect of aerodynamic lifting is to be prevented. [32]

Some immersion suits have too much buoyancy in the legs or back. Others may be inherently stable in the face down position.

3.3.5 Mechanical Protection

Ignoring the violence of small craft motions causes many injuries and man overboard accidents. The three-dimensional environment should have encouraged small craft designers to incorporate aircraft restraint systems or at least better ones than used during demolition derbies.

Common problems are drifting abeam and rolling [31], pitching while running before heavy seas [7], or just heavy breakers hitting the wheelhouse and knocking the speed out of a small vessel.

It may be assumed that many crewmembers have been knocked unconscious or died due to lack of restraint systems, hard interiors, loose objects including bodies and sharp projections. It is also evident that interiors and restraint systems of expensive life-saving equipment can be improved at relatively low cost.

The instant exposure of lifeboat occupants to wave motion and wind could be much worse than stuntflying and more violent than a schoolbus rolling down subsequent berms. It is easy to imagine the havoc caused by even one unrestrained torso inside equipment that is supposed to save lives.

Drop-off systems from as high as 20 m (65 ft) are safer, because crew restraints are designed for the initial and worst shock and the motivation to use them is clear. Survivors lashed to the mast are akin to seatbelt users and some skippers have survived by pressing their heads against a bulkhead before each wave impact.

3.3.6 Thermal Protection

Hypothermia is the most important ocean survival problem. [9] [67] Equipment designers need accurate data, showing specific heat loss in water for various body areas. Infra red scans are helpful. [65]

Available information allows general conclusions. Equipment needs to suit a passive victim without injury, implying a maximum permissable heat loss per average person of 145W (500 Btu/hr) [47] [48] [62] [66]

This translates into about 40mm ($1\frac{1}{2}$") of closed cell foam near the skin or 40mm ($1\frac{1}{2}$") in the floor of a liferaft when dry inside and about 100mm (4") in the air-exposed canopy. [49]

The 10mm (3/8") of closed cell neoprene in divers' suits corresponds with a moving person producing 580W (2000 Btu/hr)

For deckhands we have the problem of hyperthermia, especially in hot weather or fire fighting and the need to wear tight-fitting clothes to prevent snagging accidents. Even the best design survival/immersion suits only allow moderate deck activities in winter. Suggestions that cross-country skiers control their temperature by removing hats and gloves are useless to the ones requiring gloves and hard hats for safety.

Wintertime hypothermia may occur before donning protective gear or taking a hot drink. Only thorough medical training may help. Unprotected victims can be out of control in 10 minutes, a good swimmer or "drown-proofer" in 15 minutes and a non-swimmer in fetal position in 20 minutes. Grossly obese persons can last much longer. [43] [44] [45] [46]

Revival without brain damage is possible, even after an hour, despite symptoms common to non- hypothermia cases, where 10 minutes without oxygen are presumed enough to cause irreversible brain damage.

External heating could be chemical (Johnson "Hotshots"), radio isotopes (Sanders Nuclear Corp.) or liquid fuel. Several excellent self-contained diesel fuel type heaters are readily available.
Food calories help longer term, internal body heat generation.

All equipment should be designed to keep a person as dry as possible. In the case of accidental puncture or leakage, flow-through of cold water is to be prevented. It is presumed that the combination of a survival/immersion suit and a liferaft or capsule would be enough to prevent hypothermia.

3.3.7 Waste Management

Severe stress in some adults who tested survival suits caused lower body core temperature, until they were asked to relax and urinate. Inappropriate survival behaviour can be prevented by MED training (see p.4)

Designers of survival suits use materials technology, borrowed from from wet and dry diving suits. Neoprene is capable of lasting over 25 years. The author questions a design philosophy based on short term re-use, cleaning, inspection, high initial and maintenance costs.

Disposable diaper technology has allowed reduction of skin rash while maintaining insulation values. Professional mariners should make protective clothing techniques part of their knowledge. Part of the outer wear and disposable underwear could be worn during storm alert periods and it would be interesting to see what a team of medical, industrial and fashion designers could do in this area.

Once in the water, an upright position of the head and torso lessens the effects of motion sickness, reducing dehydration.

3.3.8 Redundancy

Distress and erratic behaviour have to be accepted, despite the training and the drills. It seems that not one single item of equipment is capable of ensuring survival by itself and that fatalities will decrease with redundancy and "fail-safe" design.

A stabilized liferaft with full complement in immersion suits and a working ELT represent a minimum,even in relatively warm climates. [13] We also should analyze old habits during storms: sleeping in survival suits instead of under blankets may enhance survival ability.

immersion suits should allow safe pick up with a gaff because fishermen are most proficient with this tool. Lifeboats and capsules should have buoyancy bags,to prevent capsizing during people transfers. Life lines are to be used as well.

Some rafts were sunk by fishhooks; zippers could ice up; written instructions cannot be read by people who lost their glasses; bailing to the outside only; small transmitters could have manual standby power; Lifeboats should float upright while swamped.

3.3.9 External Threats

Most living creatures, like sharks, whales and giant squid are considered low risk natural hazards by all mariners and fishermen interviewed by the author. There was a surprising fear of scavenging birds, like gulls, but face masks were thought to be farfetched.

Widespread oil and gasoline fires, heavy gasses and vapours may be less prevalent during storms than oil and other floating chemicals.

Bullets, rockets, shells, bombs, missiles and mines are warfare hazards affecting the design of some equipment. For example, a radar reflecting capsule may attract missiles.

Collisions with errant waves, flotsam, ice floes, fixed platforms and coastal features are hazards to the integrity of survival capsules. A dragging anchor stabilizer could alleviate coastal collisions.

Energy absorption could be through separate devices, like bumpers, inflated tubes, [10] or deformation of the structure itself or metallic foam, plastic foam, sheet metal or rigid rimmed stabilizing skirt. Puncture resistance is vital. Tapered "pop-up" shapes have been devised to escape total crushing in ice fields.

3.3.10 Materials [68]

Fiber Reinforced Plastics (FRP) are composite materials containing glass, aramid or carbon fibres, to name a few. Fishermen claim FRP hulls burn to the waterline and Ocean Ranger publicity emphasized their poor puncture resistance.

Some aerospace engineering consultants have tested puncture resistance of cylinders made from composites, which may be interesting to lifeboat designers. Punctures are hard to fix while afloat.

Multiple sandwich structures with puncture resistant membranes from aramid weaves or polyester sheets could be one answer but simple technology transfer from lightweight armour plate research might save time.

Elastomeric materials are also in need of puncture and tear proofing. Foam-in-place materials prevent collapse of leaky compartments, but the fatigue failures induced by greater stiffness require understanding before reliable designs can be developed.

Spun olefin sheets are water repellent and gas permeable; instant foams [50], multicellular polyester fibers, disposable sanitary wear, high molecular polyethylenes are but a few examples of suitable materials for disposable equipment.

Allyl diglycol carbonate is a transparent plastic with superior fire and abrasion resistance.

Steel and aluminum are in demand as crunchable, energy absorbing shells, which are more easily repaired while afloat.

3.4 Detection

Detection is the essential link in successful survival. Speed favours the latest radio navigation and satellite location systems. They are reliable in pinpointing weak signals with great accuracy. [37] p 21 [32]

$ 100 Emergency Locating Transmitters (ELT) will soon be on the market and a French firm is reported to develop a design with a superimposed personal identifier code.

The Dartmouth Coast Guard office has been called by fishermen's wives trying to buy ELT's for Christmas. Technology will not be far off where youngsters can be equipped and located anywhere when lost.

Further developments anticipated are: Automatic Alerting Device [51] p 1101 Unscrambling multitude of signals during major storms, preventing misuse by legislation, 2 ELT's per boat [53], deckhands wearing instant overboard alerts, hand-powered squeeze type transmitters backing up run down batteries, sonar and Extremely Low Frequency (ELF) underwater radio.

Existing active detection methods include flashlights, flashers, flares, candles and rockets; whistles, noise, smoke and dye markers, mirrors, Citizen Band, Emergency Position Indicating Radio Beacons, (EPIRB's)

Existing passive methods may consist of colours, size, clusters, height, flag, reflectors [16], radar reflectors [52] p 245, [42] p 67, cable balloon, kite or autogiro. Metallized kites and balloons are feasible.

3.5 Recovery

Davits are found on most larger vessels and Dr Reg Gilbert of the Bedford Institute suggested that all ships be fitted for survivor pick up because it may take too long for rescue vessels. The following steps are suggested:

A. Calm the water; Tim Severin suggests whale oil as the best [35]
B. Dispatch a lifeboat and tow it, even at risk of damage
C. Use special device, suspended from davits, to scoop, catch and lift.

Over the side retrieval is preferred over bow or stern retrieval. Devices should be nets or baskets with upper life ring [57] and the crane or boom to be equipped with tension controlled cable [56]

Capt Allan Stockdale's supply ship is to be equipped with an electro-hydraulic crane with an outreach of 5.5m (18') Dummies have been picked up in 5m (15') swells in 15 minutes and he feels that he can pick up victims in 7.5 - 9m (25 - 30') swells, with about 20 minutes per pick up.

Towing ties up rescue vessels; towing experts contacted seem to favour shallow draft capsules, even though fast towing has caused capsizing of disc buoys. Any long floating line with suitable drogue can be picked up.

Stern ramps have been proposed for retrieval of objects but the problem is the possibility of drowning survivors in the process and the pitching and heaving of the stern presents serious problems for trawlers as well as trimmed supply ships.

Helicopter pilots suggest that helicopters are not suitable retrieval devices for floating objects, unless the water is calm. They do have an excellent record of picking survivors off ledges and stranded vessels at great risk to themselves. Heaving would just be too much of a problem.

4. DESIGN

4.1 Parameters

Table 2 lists the design parameters, with the essential ones circled.
Table 3 lists existing and proposed design options.
Table 4 is a matrix, based on tables 2 and 3, with up to four points allotted to each combination. If an essential parameter rates a zero, the design is not viable, unless improvements are made.

Calculated totals and percentages for economic and functional worth, included in the tables 3 and 4 have been plotted in Fig. 1, with the optimum designs closest to point Q, the assumed theoretical limit. Designs represented by two letters are combinations, clearly showing the value of redundancy. For further reading see [58] [59] [60] [61]

1.	Escape, Entry	dry, easy, quick, simple design
2.	Launch	expertise, listing, while moving, release from within
3.	Wet Entry	access by floating person
4.	Stand-off	connect to other capsules, allround vision
(5.)	Propulsion	active, passive, get away velocity
6.	Releasability	internal, passive, safe
(7.)	Threat Avoidance	fire, collision, animal, warfare, chemicals
(8.)	Buoyancy	reliable ?
(9.)	Stability	inherent, self-righting, wind effect
(10.)	Thermal	insulation, protection against puncture
11.	Comfort	heating, posture, soft interior
12.	Cooling	venting, hyperthermia, fresh air
13.	Waste	control, disposal
(14.)	Impact	collision, puncture tolerance
15.	Packaging	restraint system, rounded absorbing edges
16.	Detectability	electronic, visual
17.	Retrievability	transfer to safer place
18.	Towability	stability
(19.)	Heat	fire - explosion resistance
20.	Skills needed	fault tolerance, seamanship for success

Table 2 Design Parameters for value analysis

4.2 Options

Code	Brief Description	Estimated $ Incremental cost per person year	Relative Economic Worth %	Rank
A	Open Lifeboat	125	84	3
B	Enclosed FRP Lifeboat, 2 pt release	600	25	13
C	Enclosed FRP Capsule, 1 pt release	500	37.5	12
D	Enclosed FRP Lifeboat, free fall	700	12.5	14
E	Liferaft	190	76	9
F	Liferaft with large stabilizer, waterbag	220	72.5	10
G	Man in heavy clothes with ELT(see p.11)	120	85	2
H	Immersion dry suit, 10mm foam, 25mm air	150	81	4
J	High speed, rigid inflatable, open boat	170	79	7
K	FRP passive capsule prototype	170	79	7
L	Work suit with Backpack Liferaft	400	50	11
M	Dry suit, shoulder skirt, disposable, 3 day	180	77.5	8
N	Dry suit, balloon cluster,disposable,3 day	160	80	5
O	Spar Buoy, steel or FRP, 2-3 crew,4 day	150	81	4
P	Steel Capsule, 6-8 crew, 6 day	165	79	6
R	Pop-off Wheelhouse, 6-8 crew, 6 day plus	100	87.5	1
S	EFIRB(see p.12)	35	n/a	-
Q	Theoretical optimum	50	100	-
X	Theoretically worst	850	0	-

Table 3 Design Options, existing and proposed

4.3 Economic Worth

Table 3 shows the estimated annual cost per person per year as the soundest basis for comparison and is based on total write-offs for disposables of 1 year, 3 years for elastomeric products [54], 6 years for capsules up to 12 crew and 10 years for over 12 crew, including lifeboats.

Analyses of profitability, safety and the monetary value of human life have been made. [11] [12]. Interest in long write-off periods is suddenly diminishing because of the rapid pace and interest in improvements in life-saving equipment. Shelf life, maintenance, testing and training require simulated re-use [17] where the equipment hopefully never needs to be used.

Parameters from table 2 (from table 3)	existing designs											proposed designs						combinations									
	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	R	S	AH	BH	CH	GM	GN	JH	RH	PS	RS	OS
1	3	3	3	4	2	2	4	4	3	3	3	4	4	3	3	4	4	4	4	4	4	4	4	4	4	4	4
2	3	3	3	4	2	2	4	4	2	3	4	4	4	2	3	3	4	4	4	4	4	4	4	4	4	4	4
3	3	2	2	2	3	3	0	2	4	1	4	1	1	0	2	2	0	3	3	3	1	1	4	2	2	2	0
4	2	2	2	3	3	4	3	3	2	3	1	3	2	3	3	3	4	3	3	3	3	3	3	3	4	4	4
5	3	4	4	4	2	1	1	2	4	1	1	2	2	1	1	1	0	3	4	4	2	2	4	2	1	1	1
6	3	3	3	3	3	3	4	4	2	3	4	4	4	2	3	3	4	4	4	4	4	4	4	4	4	4	4
7	3	4	4	4	1	1	2	2	4	1	1	2	2	1	2	2	4	3	4	4	2	2	4	2	4	4	1
8	2	3	3	3	2	2	1	3	3	4	3	3	4	4	4	4	4	3	3	3	3	4	3	4	4	4	4
9	1	1	3	2	1	3	2	2	3	3	2	4	4	4	3	3	4	2	2	3	4	4	3	3	4	4	4
10	1	2	2	2	2	2	0	3	1	3	2	3	3	4	4	4	v	3	3	3	3	3	3	3	4	4	4
11	0	1	0	1	0	0	0	0	0	0	0	0	0	0	4	4	v	0	1	0	0	0	0	4	4	4	0
12	4	2	2	2	3	3	4	4	4	2	4	4	4	2	3	4	v	4	4	4	4	4	4	4	3	4	2
13	1	2	2	2	1	1	1	1	1	3	1	2	2	1	2	4	v	1	2	2	2	2	1	4	2	4	1
14	1	1	2	2	2	2	2	2	3	2	2	2	2	3	3	2	3	2	2	2	2	2	3	2	3	3	3
15	1	2	2	4	2	2	1	1	1	3	1	1	1	3	4	4	4	1	2	2	1	1	1	4	4	4	4
16	2	3	3	3	1	1	3	1	3	3	1	2	2	1	3	4	4	2	3	3	3	3	3	4	4	4	4
17	3	2	2	2	2	1	3	3	2	2	3	3	3	2	2	2	3	3	3	3	3	3	3	3	3	3	3
18	3	3	2	3	2	1	1	1	3	2	1	1	1	2	2	2	1	3	3	3	1	1	3	2	2	2	2
19	0	4	4	4	1	1	0	0	1	3	0	0	0	3	4	4	2	0	4	4	1	1	1	4	4	4	3
20	1	2	2	2	3	3	4	4	1	3	4	4	4	2	2	2	4	4	4	4	4	4	4	4	4	4	4
Total	39	49	50	56	38	38	40	46	47	48	42	49	49	43	57	61	49	52	62	62	51	52	59	67	68	71	56
%	49	61	63	70	48	48	50	58	59	60	53	61	61	54	71	76	X	65	78	78	64	65	74	84	85	89	70

Table 4 Value analysis matrix; functional performance factors vs design options

Disposable personal gear can be written off as an expense or it could be offered for sale to passengers. Low cost automotive survival suits are meeting with public approval. Fishermen who will not spend $ 500 for an immersion suit seem to be quite interested in $ 100 disposable suits, if available. Some masters complain that blaze orange suits are worn in hunting camps by those refusing to wear them on board.

4.4 Functional Worth

Table 4 is trying to show what goes on in a designer's mind in rating and optimizing various design solutions.
Many of the choices are arbitrary and show the bias of one individual. Scrutiny of these judgments is essential.

4.5 Value Analysis

For purposes of this report, the author used Value Engineering [59] [60] to arrive at his recommendations. Others can use the same technique in ranking any number of competing designs. The more facts available before decision time, the better the result. Even subtle, psychological factors can be taken into consideration. It has been found that weighting, increasing or decreasing the number of factors and minor variations from person to person have surprisingly little effect on the end result. [58] [61]

Value Analysis helps formalize the largely intuitive approach of many designers and increases the understanding of the purpose of design:
"Doing more with Less"

4.6 Preliminary Conclusions

Fig. 1 shows that designs RS,R,PS,RH,P,OS of table 4 are the best. Lifeboats and capsules are not necessarily optimum solutions despite their high functional worth. The author also analyzed combinations of just the vital design parameters and finds RS,PS,R,O,J,P as optimum solutions. The correlation between the first three is worth noting.

4.7 Prognosis

Life saving equipment, now considered a waste of valuable space, should probably become an integral part of the useful space aboard, capable of becoming or remaining a command module in its own right, like a detachable wheelhouse. Recreational or sleeping space on oil rigs could become detachable and droppable, with soft interior, even allowing safe capsizing as a one time event. Watertight superstructures may cost less than conventional ones with lifeboats.

In the case of immersion suits, two directions are clear: one is clearly trending towards low cost passenger suits for less than $ 100 and the other a further gradual refinement of professional suits, which serve other purposes, like pilots, rescue personnel, fishermen on larger boats, etc.

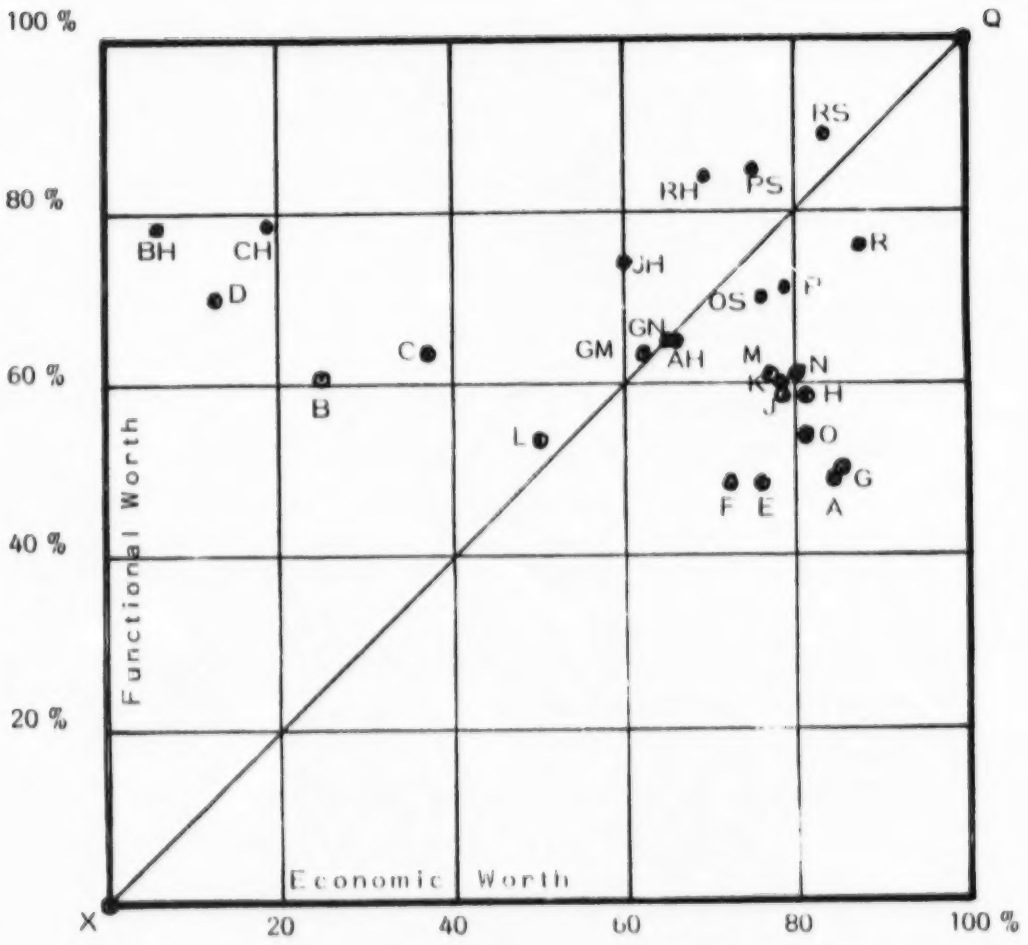

FIG. 1 Optimization Diagram

This diagram is a combination of Tables 2,3 and 4 and shows the "strongest" designs in the top right hand corner. "Stronger" designs are the ones with the best combination of functional and economic qualities, indicating their probable success potential in the marketplace.

This method is also used in the development of optimum designs and design details. There is potential for using the same method in deciding the award of contracts and bid evaluation.

The key to the abbreviations or code indicating each design option can be found in Table 3, p.14. Multiple code letters indicate combinations, e.g. RS is a pop-off wheelhouse with 6 day survival ability and equipped with an emergency position indicating radio beacon. The reader is invited to check the value of a person in heavy clothes with an emergency locating transmitter (G) inside a liferaft with waterbag stabilizer (F).

5. RECOMMENDATIONS

Based on this limited study, the following recommendations can be made:

5.1 Further work

Time did not permit to develop rigorous cost figures for better value analysis. Various reviewers' suggestions to include a weighting factor to reflect the survival time was well taken. Never before has design optimization work included total failure as an expected outcome based on time. It would require some original work in advancing the techniques of value engineering and probably result in three dimensional graphs.

Therefore further work should include more extensive economic analysis as well as assessing the survival time expectations for each combination.

5.2 Safety Management

Most existing equipment can be improved readily at fairly low cost by incorporating some of the criteria identified in this report. Combinations of existing equipment greatly enhance survival ability. While MED courses have not been analyzed in this study, nobody should be on the ocean without recently learned survival training.

It is important for naval architects to have criteria available for the worst possible combinations, such as providing for the safety on passenger liners and ferries, including the percentage of less mobile or handicapped persons permitted.

Fishing boats should be equipped with non-capsizing bags which have been successfully tried in Japan.

5.3 Legislation

The most important action of authorities, having jurisdiction is to back their officials in the work they are doing to promote safety. There are areas where small changes in requirements would have major benefits, such as the safe swamping behaviour with watertight superstructures, air bags or foam injection.

Mandatory electronic detection equipment would be a low cost complement to the recently launched satellite systems, which have already proven their worth.

5.4 Design Management

It is feasible to develop survival/immersion suits of low cost. At a selling price of less than $ 100 every fisherman would buy one. Some of these new suits may be available within a year.

Safety information could be prominently displayed in graphic form along escape routes on board. The services of a graphic designer or industrial design consultant would be essential.

Survival command post capsules on high risk vessels would allow multiple use of available space and probably help eliminate the wasted space and top heavy weight caused by conventional lifeboats.

The development of smaller, lower cost, tension controlled cranes, booms and davits would be a boon to small vessel operators and allow them

to become rescue vessels in case of emergency.

5.5 Research and Development

During the study, many areas of ignorance were identified. For example, stability testing of ships or models under simultaneous storm and emergency conditions, such as the loss of power is not common.
It has enhanced the author's respect for the surviving mariners.

The float-off concept should be further developed for wheelhouses, but it should be preceded by the development of inherently stable 6 man steel capsules, capable of being manufactured anywhere.

The development of a spar buoy capsule, capable of being dropped from great heights and having reduced heaving behaviour would be desirable.

Developing a method to successfully inject foam flotation into liferafts should not be expensive. Author developed conceptual designs.

The development of oarless, man-powered propulsion systems as indicated in the text should be encouraged. A fourth year Waterloo University student has started experiments with flipper propulsion.

Other areas where the author has found only word of mouth information and very little research data, vital to the successful design of small ocean going survival capsules are:

Instant flexible foam technology
Towing behaviour of various rotational shapes
Dynamics of deep Vee hulls with square-faced superstructures
Aerodynamics of a hemisphere at the water/air interface
Adhesion of surfaces to turbulent water flows
Chemicals turning seawater to gel or non-buoyant insulators
Drag coefficients for warps of various diameters and lengths
Deceleration of various blunt objects on perpendicular water impact

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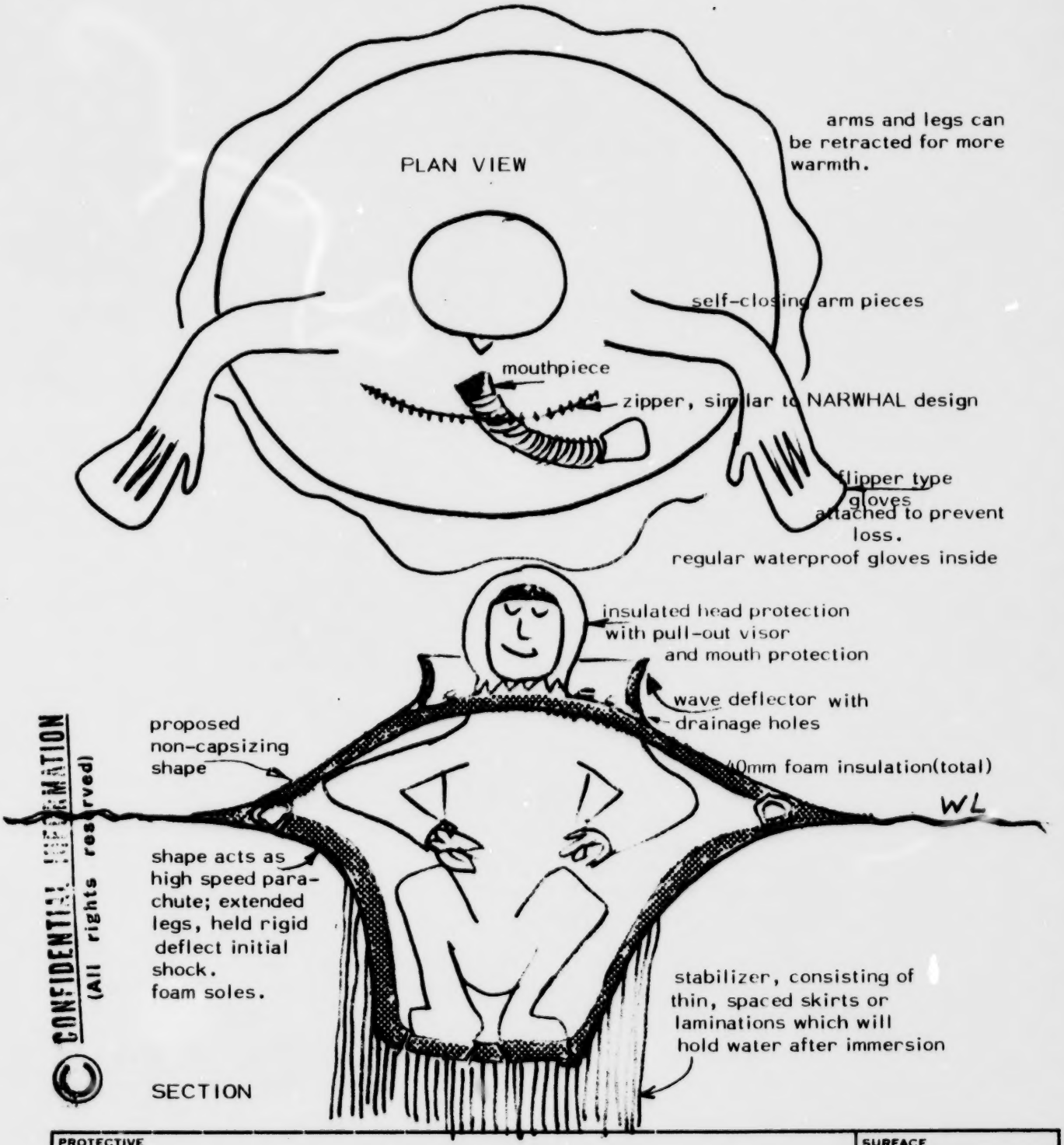
PLAN VIEW
arms and legs can be retracted for more warmth.
self-closing arm pieces
mouthpiece
zipper, similar to NARWHAL design
flipper type gloves attached to prevent loss.
regular waterproof gloves inside
insulated head protection with pull-out visor and mouth protection
wave deflector with drainage holes
proposed non-capsizing shape
40mm foam insulation(total)
WL
shape acts as high speed parachute; extended legs, held rigid deflect initial shock.
foam soles.
stabilizer, consisting of thin, spaced skirts or laminations which will hold water after immersion
SECTION

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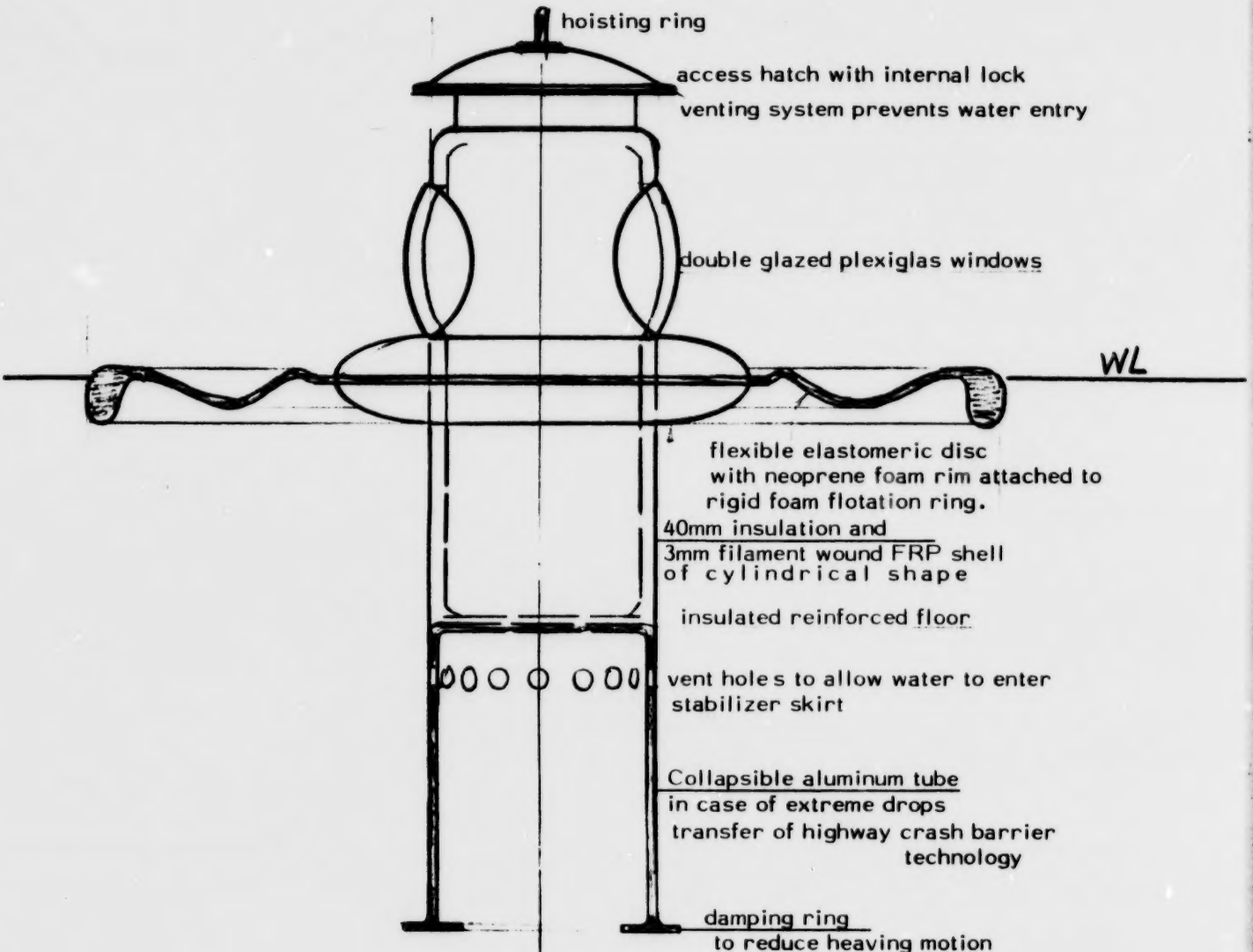
PROTECTIVE FINISH:						SURFACE ROUGHNESS IN MICRO INCHES:
MATERIAL: Neoprene foam or better						
3RD ANGLE PROJECTION	DIMENSIONS ARE IN INCHES MM	TOLERANCES: ON FRACTIONS: ±	DECIMALS: ±	ANGLES: ±		UNLESS OTHERWISE SPECIFIED
DRAWN: Van Leeuwen	83-02-01	SCALE: none	DWG. SIZE: 1	NEXT ASSY:	SHEET OF	
CHECKED:		TITLE: SOFT MARINE CAPSULE CONCEPT	DWG. NO. FIG 2		ISSUE	DATE
APPROVED:						
SUPERSEDES:		Bert van Leeuwen Industrial Design Ltd.			AMHERST NOVA SCOTIA	
CLIENT:						



Unit is also equipped with retractable antenna and radar reflector;
2 or 3 person units would allow standing room only.
bicycle seating could be incorporated.

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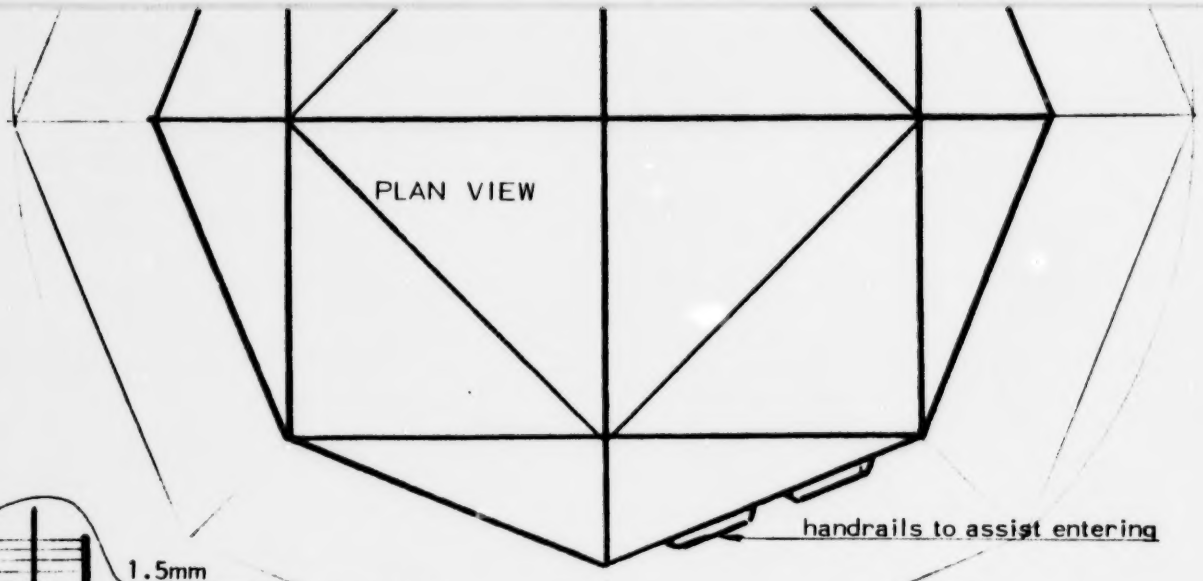
PROTECTIVE FINISH:					SURFACE ROUGHNESS IN MICRO INCHES:	
MATERIAL:						
DIMENSIONS ARE IN INCHES MM		TOLERANCES: ON FRACTIONS: ±	DECIMALS: ±	ANGLES: ±		UNLESS OTHERWISE SPECIFIED
DRAWN: van Leeuwen	83-02-15	SCALE: none	DWG. SIZE: 1	NEXT ASSY:	SHEET	OF
CHECKED:		TITLE: HARD SHELL MARINE CAPSULE CONCEPT		DWG. NO. FIG. 3	ISSUE	DATE
APPROVED:						
SUPERSEDES:		Bert van Leeuwen Industrial Design Ltd.			AMHERST NOVA SCOTIA	
CLIENT:						



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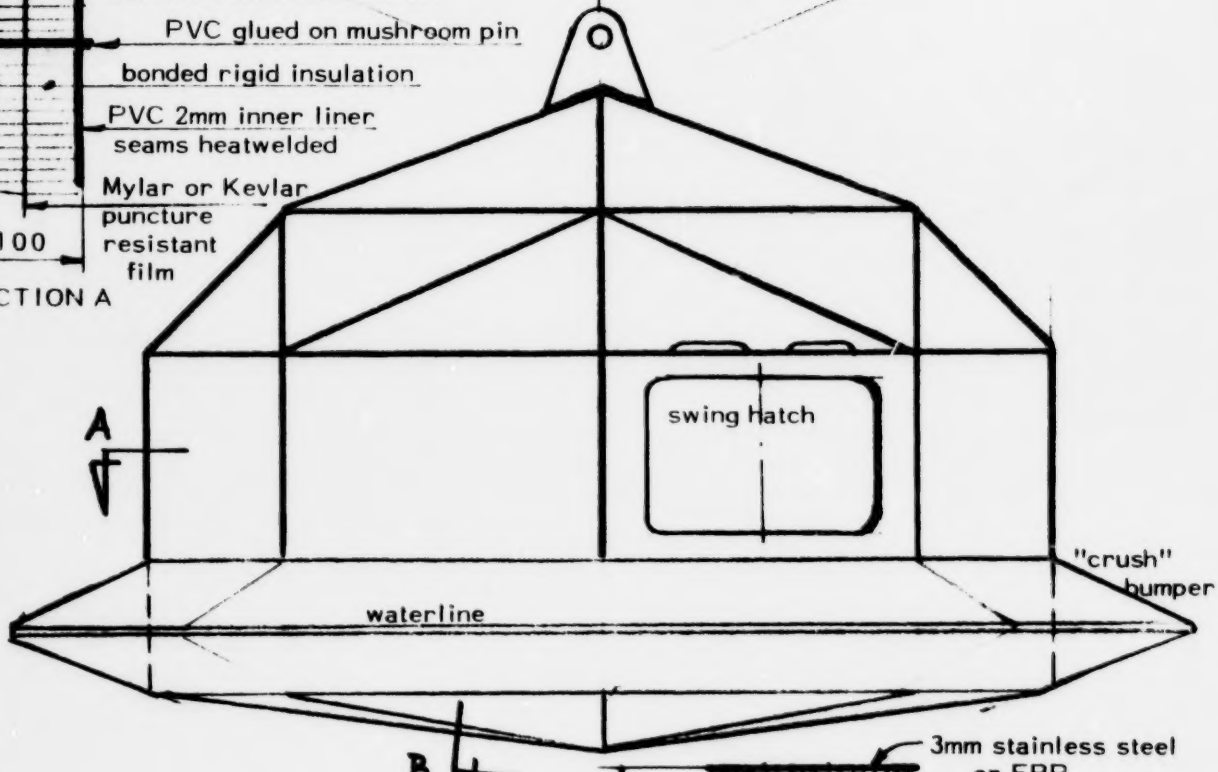

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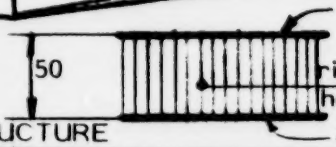

BONDED SANDWICH STRUCTURE

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PROTECTIVE FINISH:					SURFACE ROUGHNESS IN MICRO INCHES:	
MATERIAL:						
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DRAWN: van Leeuwen	83-03-12	SCALE: none	DWG. SIZE: 1	NEXT ASSY:	SHEET	OF
CHECKED:		TITLE: STEEL SHELL		DWG. NO.	ISSUE	DATE
APPROVED:		MARINE CAPSULE CONCEPT		FIG 4		
SUPERSEDES:		Bert van Leeuwen Industrial Design Ltd.			AMHERST NOVA SCOTIA	
CLIENT: W R Benjamin Products Limited						

BERT VAN LEEUWEN INDUSTRIAL DESIGN LIMITED
11 Princess Street Amherst Nova Scotia B4H 1W5 – Phone (902) 667-3464

date: 31 August 1983 Reference No.: TC83081
Sheet 1 of 2

Client: Transportation Development Centre, Montreal

D E S I G N P R O P O S A L (Preliminary Estimate)
covering: Soft Marine Capsule

This Proposal covers the design services checked below, based on the Client's directive s to the Designer:

Service:	Included in fee	Extra
consultation	✓	
research; analysis	✓	
reporting	✓	
preliminary design	✓	
presentation	✓	
conceptual design	✓	
hand sketches	✓	
prototype sketches	✓	
accurate layout		
lofting; lines drawing	✓	
photography; graphics		
assembly drawings	✓	
detail drawings	✓	
parts lists	✓	
materials list	✓	
specification -notes	✓	
illustrations; artwork	extra	
supervision of:		
inspection of:		
cost estimating		
travelling out of town	extra	
calling tenders/quotes		
production+tool planning		
plant layout		
machine design		
tool design		
design changes		
as-built drawings	extra	
oper/mainten.manuals	extra	

Fixed Fee Agreements honour a fifteen percent (15%) variance from the quoted total, according to actual time records.

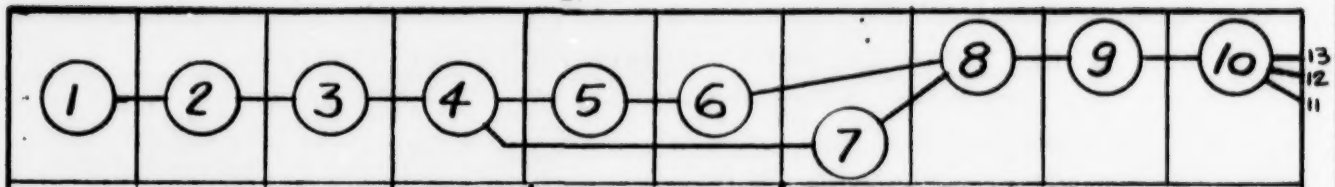
Professional charges are net and due within 30 days from the invoice date. Unless agreed otherwise, progress payments will be invoiced monthly.

The Client is entitled to receive up to four sets of prints off working drawings without additional charge.

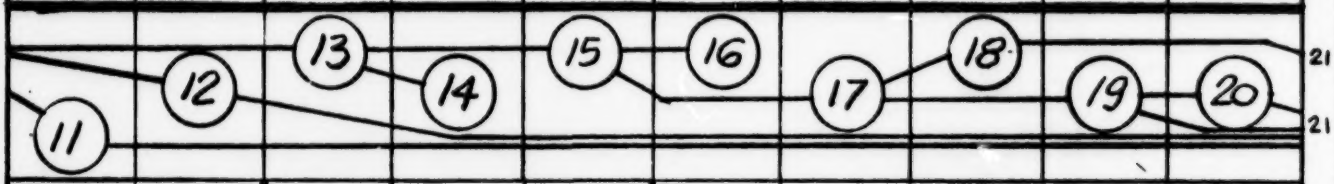
This Proposal may be withdrawn by us if not accepted within N/A days.

Estimated Development Cost:

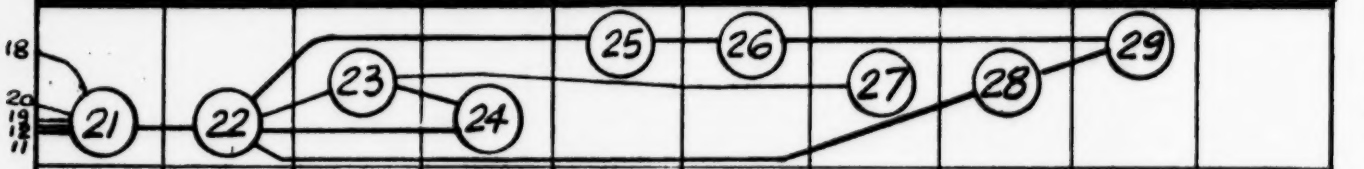
Research and Development Engineering, Management	$ 60 000
Prototyping	$ 30 000
Total	$ 90 000



EXPLORATION/EARLY DEVELOPMENT				MOCK-UP STAGE	← PROTOTYPE STAGE				
Starting date research	Specifications complete *	Tentative schedule complete *	First design sketches made *	Mock-up made Optional *	Experimt. testing concluded	Decide quantity & date *	Detail parts made	Assembly complete *	Laboratory tests complete *
2 Jan 84	13 Jan 84	17 Jan 84	24 Jan 84	15 Mar 84	27 Jul 84	27 Jul 84	17 Sep 84	1 Nov 84	15 Nov 84



PROTOTYPING →	PRE-MARKETING STAGE			← PRE-PRODUCTION STAGE →				
Apply to testing agencies CSA, UL etc.	Field testing complete	Cost and looks approved *	Picture taking for sales	Decide pre-production quantity *	Send P.O for special equipment	Templates Part dwgs made	Dies made	Tools approved first run *	First assembly; find flaws *
		MANUFACTURER'S INVOLVEMENT							
X	6 Jan 85	6 Jan 85	10 Jan 85						



incorporate final remarks by shop, QC, CSA sales *	official drawing release	Spec. sht + advert. info ready *	Memo to sales dept.	Change Notice on Eng. order + eff. date	Mainten. + Operating Manuals printed	Replacement P/L + Dealer info printed	Wiring diagram printed	CSA, UL testing wind-up final fee labels ready *	remarks

*) Review and Evaluation

DRAWN: van Leeuwen	31 Aug 83	SCALE: ----	DWG. SIZE: 1	NEXT ASSY:	SHEET 2 OF 2	
CHECKED:		TITLE: DEVELOPMENT SCHEDULE Soft Marine Capsule		DWG. NO. TC 83081	ISSUE	DATE
APPROVED:						
SUPERSEDES:		Bert van Leeuwen Industrial Design Ltd.			AMHERST NOVA SCOTIA	
CLIENT: TDC Montreal						

BERT VAN LEEUWEN INDUSTRIAL DESIGN LIMITED

11 Princess Street Amherst Nova Scotia B4H 1W5 – Phone (902) 667-3464

date: 31 August 1983 Reference No.: TC 83082

Sheet 1 of 2

Client: Transportation Development Centre, Montreal

D E S I G N P R O P O S A L (Preliminary Estimate)
covering: Hard Shell Marine Capsule

This Proposal covers the design services checked below, based on the Client's directive s to the Designer:

Service:	Included in fee	Extra
consultation	✓	
research; analysis	✓	
reporting	✓	
preliminary design	✓	
presentation	✓	
conceptual design	✓	
hand sketches	✓	
prototype sketches	✓	
accurate layout	✓	
lofting; lines drawing		
photography; graphics		
assembly drawings	✓	
detail drawings	✓	
parts lists	✓	
materials list	✓	
specification -notes	✓	
illustrations; artwork	extra	
supervision of:		
inspection of:		
cost estimating		
travelling out of town	extra	
calling tenders/quotes		
production+tool planning		
plant layout		
machine design		
tool design		
design changes		
as-built drawings	extra	
oper/mainten.manuals	extra	

Estimated Deve lopment Cost:

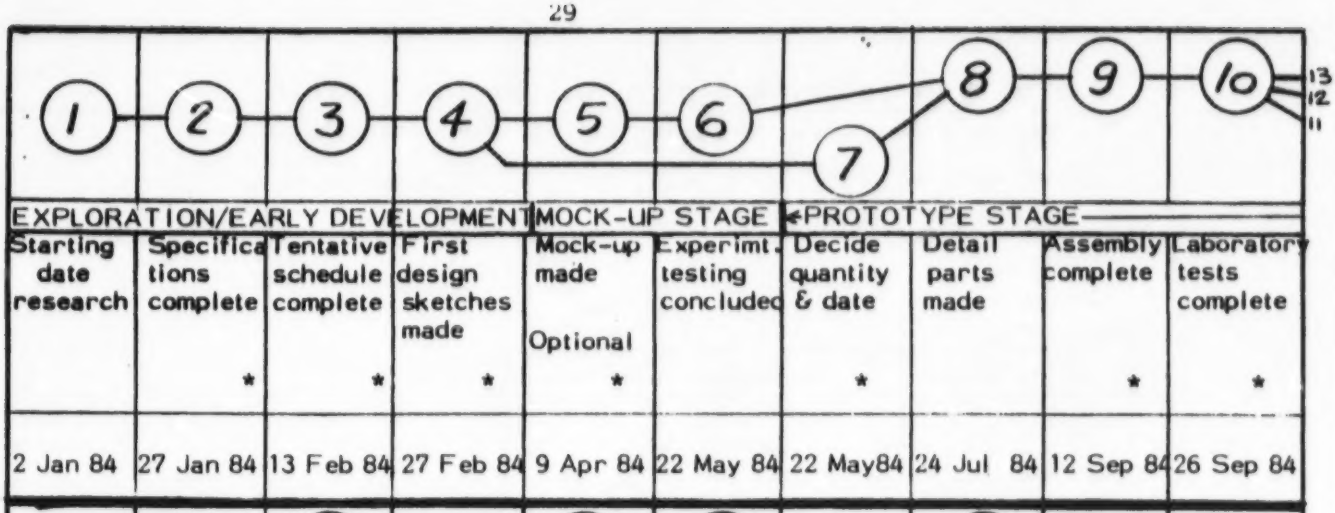
Research & Development, Engineering, Management:	$ 50 000
Prototyping:	$ 50 000
Total:	$ 100,000

Fixed Fee Agreements honour a fifteen percent (15%) variance from the quoted total, according to actual time records.

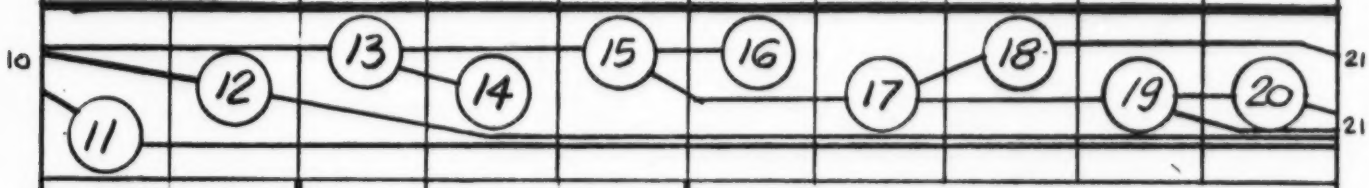
Professional charges are net and due within 30 days from the invoice date. Unless agreed otherwise, progress payments will be invoiced monthly.

The Client is entitled to receive up to four sets of prints off working drawings without additional charge.

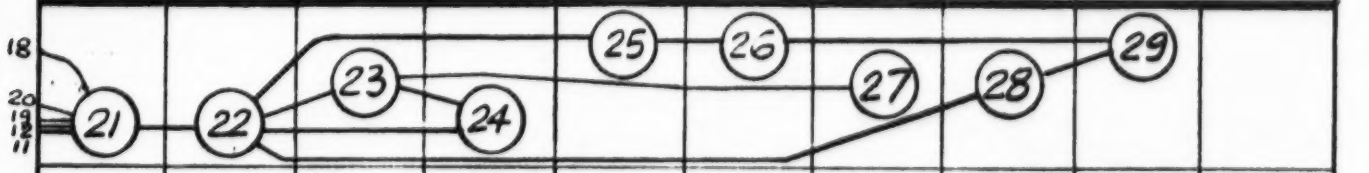
This Proposal may be withdrawn by us if not accepted within N/A days.



EXPLORATION/EARLY DEVELOPMENT				MOCK-UP STAGE		←PROTOTYPE STAGE			
Starting date research	Specifications complete *	Tentative schedule complete *	First design sketches made *	Mock-up made Optional *	Experimt. testing concluded	Decide quantity & date *	Detail parts made	Assembly complete *	Laboratory tests complete *
2 Jan 84	27 Jan 84	13 Feb 84	27 Feb 84	9 Apr 84	22 May 84	22 May84	24 Jul 84	12 Sep 84	26 Sep 84



PROTOTYPING →	PRE-MARKETING STAGE			← PRE-PRODUCTION STAGE →				
Apply to testing agencies CSA, UL etc.	Field testing complete	Cost and looks approved *	Picture taking for sales	Decide pre-production quantity *	Send P.O for special equipment	Templates Part dwgs made	Dies made	Tools approved first run *	First assembly; find flaws *
		MANUFACTURER'S INVOLVEMENT							
	12 Nov 84	12 Nov 84							



incorporate final remarks by shop, QC, CSA sales *	official drawing release	Spec. sht + advert. info ready *	Memo to sales dept.	Change Notice or Eng. order + eff. date	Mainten. + Operating Manuals printed	Replacement P/L + Dealer info printed	Wiring diagram printed	CSA, UL testing wind-up final fee labels ready *	remarks

*) Review and Evaluation

DRAWN: van Leeuwen	31 Aug 83	SCALE: ----	DWG. SIZE: 1	NEXT ASSY:	SHEET 2 OF 2	
CHECKED:		TITLE: DEVELOPMENT SCHEDULE Hard Shell Marine Capsule		DWG. NO. TC 83082	ISSUE	DATE
APPROVED:						
SUPERSEDES:		Bert van Leeuwen Industrial Design Ltd.			AMHERST NOVA SCOTIA	
CLIENT: TDC Montreal						

BERT VAN LEEUWEN INDUSTRIAL DESIGN LIMITED

11 Princess Street Amherst Nova Scotia B4H 1W5 – Phone (902) 667-3464

date: 31 August 1983 Reference No.: TC 83083

Client: Transportation Development Centre, Montreal Sheet 1 of 2

D E S I G N P R O P O S A L (Preliminary Estimate)
covering: Steel Shell Marine Capsule

This Proposal covers the design services checked below, based on the Client's directives to the Designer:

Service:	Included in fee	Extra
consultation	✓	
research; analysis	✓	
reporting	✓	
preliminary design	✓	
presentation	✓	
conceptual design	✓	
hand sketches	✓	
prototype sketches	✓	
accurate layout	✓	
lofting; lines drawing		
photography; graphics	extra	
assembly drawings	✓	
detail drawings	✓	
parts lists	✓	
materials list	✓	
specification -notes	✓	
illustrations; artwork	extra	
supervision of assembly	extra	
inspection of: parts	extra	
cost estimating		
travelling out of town	extra	
calling tenders/quotes		
production+tool planning		
plant layout		
machine design		
tool design		
design changes		
as-built drawings	extra	
oper/mainten. manuals	extra	

Estimated Development Cost:

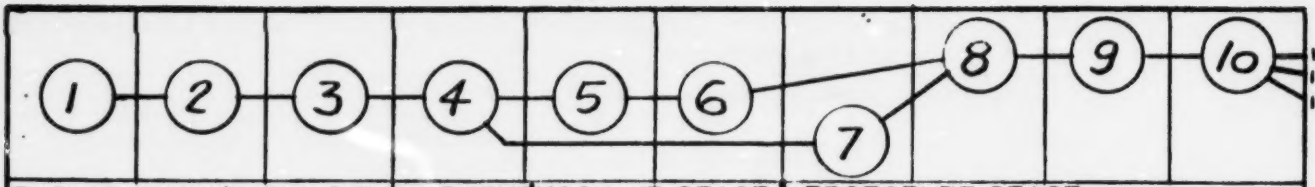
Research & Development, Engineering & Management:	$ 72 000
Prototyping:	$ 100 000
Total:	$ 172 000

Fixed Fee Agreements honour a fifteen percent (15%) variance from the quoted total, according to actual time records.

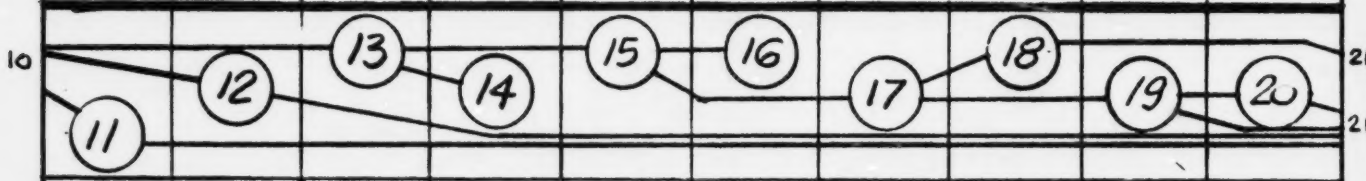
Professional charges are net and due within 30 days from the invoice date. Unless agreed otherwise, progress payments will be invoiced monthly.

The Client is entitled to receive up to four sets of prints off working drawings without additional charge.

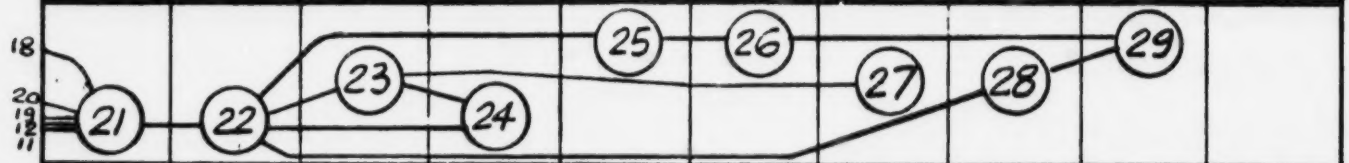
This Proposal may be withdrawn by us if not accepted within n/a days.



EXPLORATION/EARLY DEVELOPMENT			MOCK-UP STAGE		PROTOTYPE STAGE				
Starting date research	Specifications complete *	Tentative schedule complete *	First design sketches made *	Mock-up made Optional *	Experimt. testing concluded	Decide quantity & date *	Detail parts made	Assembly complete *	Laboratory tests complete *
2 Jan 84	27 Jan 84	17 Feb 84	20 Mar 84	14 May 84	3 Oct 84	3 Oct 84	19 Nov 84	24 Jan 85	8 Feb 85



PROTOTYPING →	PRE-MARKETING STAGE			← PRE-PRODUCTION STAGE →				
Apply to testing agencies CSA, UL etc.	Field testing complete	Cost and looks approved *	Picture taking for sales	Decide pre-production quantity *	Send P.O for special equipment	Templates Part dwgs made	Dies made	Tools approved first run *	First assembly; find flaws *
		MANUFACTURER'S INVOLVEMENT							
	28 Mar 85								



incorporate final remarks by shop, QC, CSA sales *	official drawing release	Spec. sht + advert. info ready *	Memo to sales dept.	Change Notice or Eng. order + eff. date	Mainten. + Operating Manuals printed	Replacement P/L + Dealer info printed	Wiring diagram printed	CSA, UL testing wind-up final fee labels ready *	remarks

*) Review and Evaluation

DRAWN: van Leeuwen	31 Aug 1989	SCALE: ----	DWG. SIZE: 1	NEXT ASSY:	SHEET 2 OF 2
CHECKED:		TITLE: DEVELOPMENT SCHEDULE Steel Shell Marine Capsule	DWG. NO. TC 83083	ISSUE	DATE
APPROVED:					
SUPERSEDES:		Bert van Leeuwen Industrial Design Ltd.		AMHERST NOVA SCOTIA	
CLIENT: T D C MONTREAL					